PERFORMANCE TESTING OF C.F.B.
GAGETOWN LOW NOx/SOx BURNERS
MARCH 1987

DSS

Contract 23440-6-9184-01-SQ

A REPORT FOR CANMET 31 JULY 87

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SUMMARY

The Canadian Centre for Mineral and Energy Technology (CANMET), with participation of DND has arranged for the installation of 2 low SOx/NOx burners in a 20 MW pulverized coal heating plant hot water generator at CFB Gagetown. The burners are staged with less than enough air for complete combustion at the burner tip. Tertiary air is supplied to a second, lower temperature combustion stage to provide enough air for complete combustion. Powdered limestone can be added with the tertiary air to react with SOx forming sulphur compounds which can be removed as particulate.

Staged burners form less NOx because of the oxygen deficiency in the very high temperature zone at the burner tip and the fact that the temperature is lower in the second stage. Introducing the limestone with the tertiary air reduces the extent of dead burning of the limestone.

SOx emissions were reduced some 30% by copulverizing limestone with the coal during baseline tests in 1982 using Ca/S ratios of approximately 3 with 2.6% sulphur coal. In March 1987 SOx emissions were reduced more than 50% by introducing powdered limestone with the tertiary air with 3% sulphur coal and with 1% sulphur coal. The Ca/S ratios was approximately 2.

A development period of several years has been required to achieve stable combustion and acceptable carbon burnout. Burner geometry and operating technique changes had achieved satisfactory combustion by the 1987 tests but the target of 50% NOx reduction has not been achieved. It is not yet clear whether a significant reduction in Nox emissions can be achieved while maintaining satisfactory levels of carbon burnout.

RESUMÉ

Le Centre Canadien de la Technologie des Minéraux et de l'Energie, Energie, Mines et Ressources Canada avec participation de Defence Nationale a été arrangé pour l'installation de deux brûleurs conçus pour diminuer le niveau de SOX et NOx dans une chaudier de charbon pulverisent. Au premier stade, au bout des bruleurs, les bruleurs N'ont pas assez d'air pour la combustion totale. De l'air tertiaire est fourni pour un deuxieme stade d'une température moins élévee pour fournir assez d'air pour une combustion complète. Du calcaire en poudre peut être ajouté à l'air tertiaire pour reagir avec SOx en faisents les composés à soufre qui peut être enlevés comme particule.

Les brûleurs en stade forment moins de NOx à cause du déficient d'oxygène dans la zone de temperature trés elevée au bout de brûleur, et le fait que la température est moins élévee au deuxième stade. En mettant le calcaire avec l'air tertiaire on reduit le degré de calcaire passiff.

Les'emission de SOx ont été reduites de 30% (approx) en ajoutant le calcaire avec le charbon durant les tests basés de 1982 avec les proportion Ca/S de 3 (approx.). En mars 1987, les émissions de SOx ont été reduites de plus de 50% en mettant du calcaire en poudre avec l'air tertiaire avec charbon de 3% souffe et avec charbon de 1% soufre et les proportion Ca/s de 2 (approx.).

Une période de 3 annees de development a été requise pour atteindre la combustion stable et suffisament complete. Les changements dans la geometerie des brûleur et les changements de la technique d'operation ont acheve's de la combustion statisfaisants avant les tests de 1987.

Le but de 50% reduction du NOx n'a pas été atteint. Ce n'est pas clair si une réduction importante dans l'emission du NOx peut etre achevée.

TABLE OF CONTENTS

	PAGE
1 INTRODUCTION	1
2 OBJECTIVES	6
3 EXPERIMENTAL PROCEDURES	6
4 EXPERIMENTAL RESULTS	8
4.1 OPERATING CONDITIONS	9
4.2 RESULTS - SO2 EMISSIONS	9
4.3 RESULTS - NOx EMISSIONS	13
4.4 RESULTS - CARBON BURNOUT	15
4.5 RESULTS - TEMPERATURES AND FLUE GAS LOSSES	15
4.6 RESULTS - PRIMARY AIR FLOW	16
4.7 RESULTS - SECONDARY/TERTIARY AIR FLOW	16
4.8 RESULTS - BOILER EFFICIENCY	17
5 DISCUSSION OF RESULTS	18
6 CONCLUSIONS	18
7 RECOMMENDATIONS	19
APPENDIXES	20

List of Illustrations

		Page
Figure 1:	Steinmuller burner with additive injection	3
Figure 2:	Section View of CE-Lamont Hot Water Boiler	4
Table 1:	March 1987 Gagetown Tests, before blr. cleaning	10
Table 2:	March 1987 Gagetown, using base coal	11
Figure 3:	SO2 reduction vs Ca/S Ratio Comparing 1987 & 1985 1/2 Load Tests	12
Figure 3b:	NOx for Various Test & Conditions	12
Figure 4:	Unburnt Carbon Losses for Various Tests & Conditions	14
Figure 5:	Boiler Efficiencies for Various Tests & Conditions	14

PERFORMANCE TESTING OF C. F. B. GAGETOWN LOW NOx/SOx BURNERS

FEB./MARCH, 1987

ABSTRACT

The report describes performance tests performed in late February and early March 1987 together with changes in design and operating procedure to the low NOx/SOx pulverized coal burners installed in Unit No 2 at the Central Heating Plant, CFB Gagetown. These burners were originally designed by Steinmueller of Germany but modifications have been required.

The low NOx/SOx burners are staged with primary, secondary and tertiary air to reduce NOx emissions. Powdered limestone, introduced with the tertiary air, enters the cooler combustion zone to avoid dead burning in the higher temperature zone near the burner tip.

The Gagetown program, which is aimed at contributing to the reduction of acid rain emissions, is described in a series of reports by G. A. Robb Associates beginning with the report on 1982 baseline tests (see references). The Scientific Authority for this program is Mr. G. K. Lee, Manager, Combustion and Carbonization Research Laboratory, CANMET, Energy, Mines and Resources Canada.

1 INTRODUCTION

Emissions of nitrogen and sulphur oxides from coal fired power plants are major contributors to acid rain and other pollution problems. Staged combustion technology is generally less capital intensive than flue gas scrubbers, and is economic to implement when boiler capacity factors are relatively low. In these situations scrubbers are not generally deemed to be justified.

The Canadian Centre for Mineral and Energy Technology (CANMET),

Energy, Mines and Resources Canada, with participation of the Department of National Defence and the co-operation of Environment Canada, awarded a contract to Volcano Inc. of St. Hyacinthe, Quebec for the installation and commissioning of two low NOx/SOx burners at CFB Gagetown. The burners illustrated in Fig. 1 were designed by Steinmueller of West Germany, and were installed in Unit No 2 of the Central Heating Plant, shown in Fig. 2. Further information is available (1).

Baseline testing with on Unit No 2 with the original CE burners was conducted during 1982 and the results are given in Appendix A. Performance testing of the Steinmueller burners, and subsequent modifications, were conducted during 1984 and 1985. The results of these tests and burner the modifications have been reported previously (1). Further modifications developed by the Carbonization and Combustion Laboratory of CANMET and CFB Gagetown personnel were required because of flame instability and excessive carbon carryover. These were carried out during 1986.

In 1986 the vanes which had been installed in the coal annulus (1) were removed and a ring of small platelets was installed at intervals on the inside of the outer coal gun tube at the outlet end at right angles to the inner surface. The swirl vanes were also removed from the oil burner because they retarded the aerodynamic mixing induced by the secondary air vanes. It was concluded that one of the main contributors to excessive carbon carryover was the high coal stream velocity at the coal gun tip. The reduction in diameter of the core pipe, after the 1984 tests and before the 1985 tests, increased the coal-conveying outer annulus area and reduced the velocity. Prior to the 1987 tests, a further reduction in velocity was achieved by reducing the primary air volume substantially. During the supervised tests by Steinmueller, the operation the primary air flow indicator was kept at about 40. Experimentation by CFB operating staff

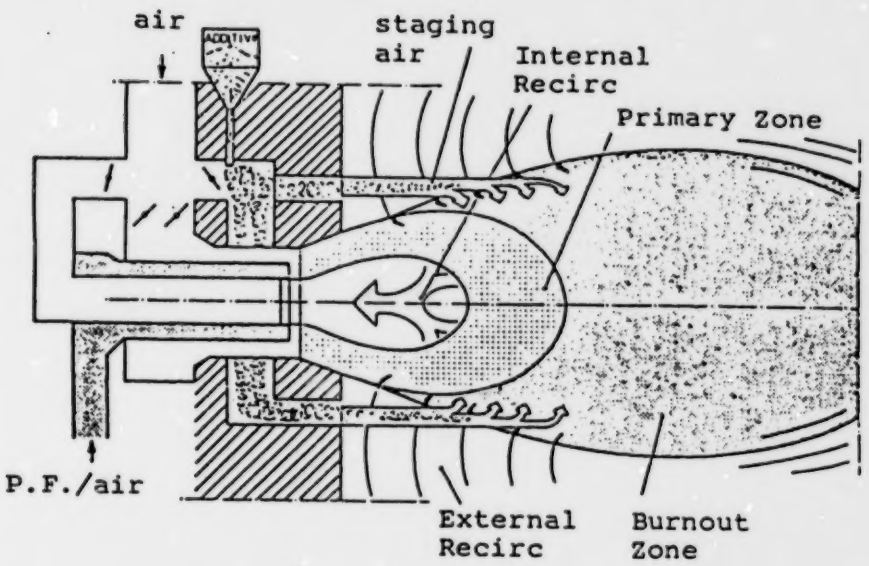


Figure 1 SM-burner with additive injection

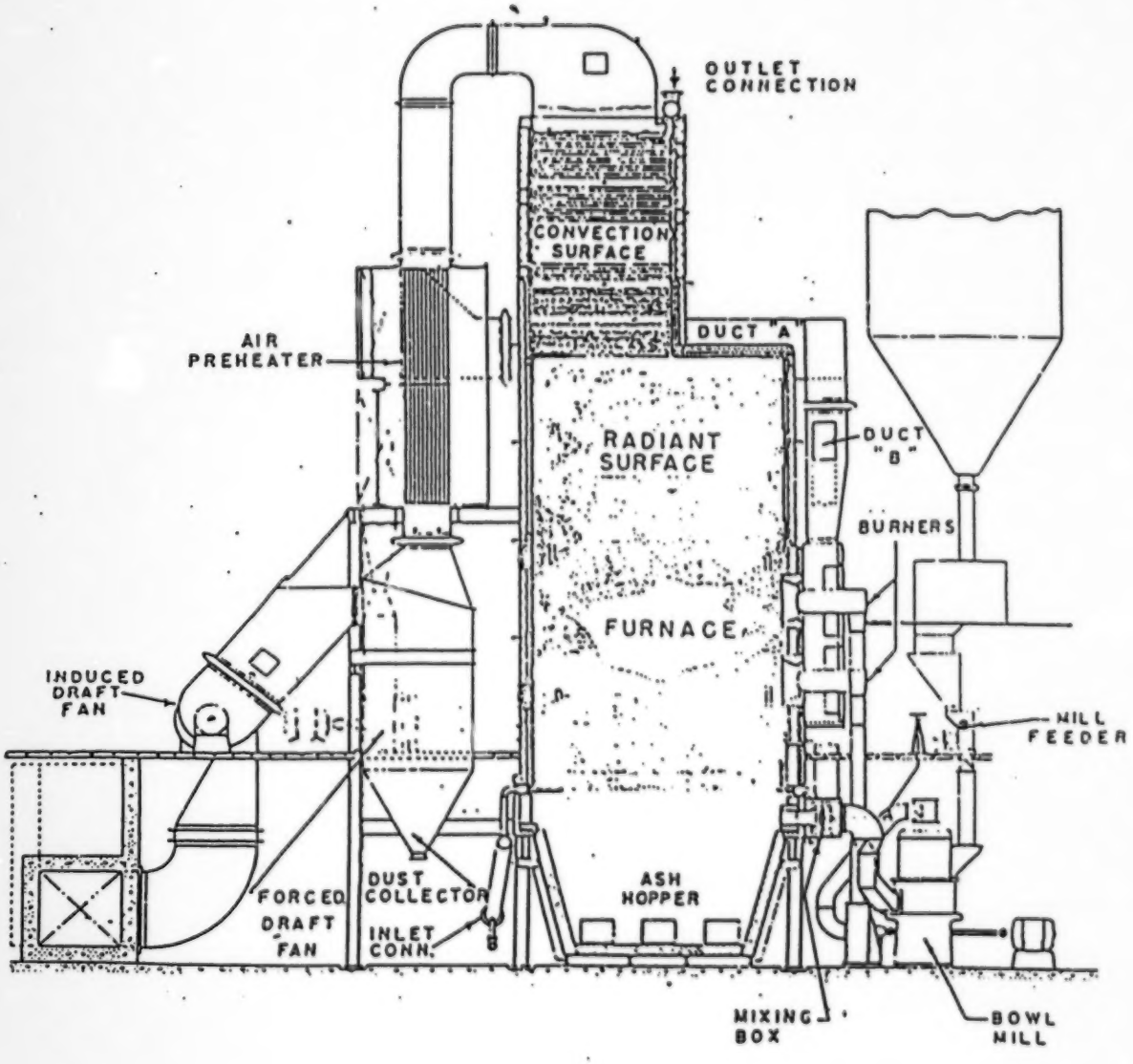


Figure 2 Section View of CE-Lamont Hot Water Boiler

demonstrated that an improvement could be achieved by reducing this setting to about 22. This brought the velocity to as low a level as is prudent, given the need to convey the coal and to prevent flash back.

Experimentation with swirl positions and tertiary air volume also improved operation. Prior to the 1987 tests the swirl indicator was set at 125 mm. The tertiary air flow cannot be measured but the fact that the tertiary air windbox pressure was negligible compared with several centimeters of water in the secondary air windbox indicates very low tertiary air flow compared with secondary air flow. Damper position indications are not a reliable measure of secondary air/tertiary air ratio.

The installation of sight ports in the furnace rear and side walls and in the furnace roof by the plant staff was largely responsible for the successful optimization of the swirl settings. These ports allowed the flame to be viewed and hence shaped so that wall impingement did not occur and allowed a clear view of ash build up and slagging on the furnace walls and burner throat.

The changes in burner geometry and operating procedure achieved a dramatic improvement in ignition, combustion stability, furnace pressure stability (much less puffing) and carbon carryover. The ring of platelets inside the end of the outer tube of the coal gun appeared to improve coal distribution at the burner tip and improve ignition. This led to more stable combustion. However, the changes impaired the NOx reduction capability of the burners.

Slag build up in the burner throat was extensive during extended periods of operation with the test coal. Whether or not this will be an on going problem with base coal has yet to be determined but it should not be a problem with coal having a relatively high ash fusion temperature.

Prior to the 1987 tests the operation of the limestone system was improved by installing a check valve to act as a vacuum breaker in the compartment below the impingement plate of the limestone metering device. This eliminated the need to periodically prevent a vacuum under the impingement plate by manually bleeding in air. A vacuum at that point causes an error in flow measurement.

G. A. Robb Associates, on behalf of EMR, provided overall coordination for the test program between February 28 and March 4 and between March 11 and March 13, 1987. This firm was also responsible for boiler efficiency determination by the loss method, measurement of air and gas flows and calcium/sulphur mole ratio determination.

2 OBJECTIVES

The objectives of the current testing program were to evaluate the performance of the modified burners, obtain data which would help in developing further improvements and indicate whether further improvement are necessary.

3 EXPERIMENTAL PROCEDURES

Each test lasted approximately an hour and a half. For each condition, two tests were run without limestone to serve as a base. Then one or more pairs of tests were run with limestone. In general the aim was to keep Ca/S ratios low because low limestone feed rates are more economic. Some time was spent experimenting with adjustments to the swirl position and the secondary/tertiary air ratio prior to commencement of the tests. Some adjustment of secondary/tertiary air ratio was attempted between sets of tests but in the time available it was not possible to improve significantly on the settings which had been established by the operating staff prior to the tests.

The analysis of test coal, base coal & limestone are in Tables 1 and 2. The sulphur level of the test coal was approximately 3% and that of the regular base coal approximately 1%. The limestone was 96% calcium carbonate for the tests on both coals.

Because of the high temperature problems mentioned in Section 4.1 most of the tests were run at half load with the lower burner. The only tests with both top and bottom burners were on Mar. 13.

The Environment Canada emission measurements were taken between the cyclone collectors and the large settling chamber near the stack. Nitrogen oxide, sulphur dioxide, oxygen, CO2, THC and CO were monitored continuously. Particulate matter concentrations were also determined.

G. A. Robb Associates measured oxygen on a dry basis, CO and the air preheater outlet temperature to provide data for boiler efficiency determinations by the loss method.

The limestone feeder was calibrated on February 27/87 at 40% of capacity. The calibration data are in the Appendix D. Limestone feedrates were set for target Ca/S ratios using limited data available on coal sulphur levels.

A small raw coal sample was collected at the pulverizer inlet every 15 minutes during each test to obtain a blend representative of a particular test. A pulverized coal sample was taken at the pulverizer outlet every 15 minutes. With two burners operating the sample was taken alternately from the pulverizer for the upper and lower burner every 15 minutes. With only the lower burner operating, the pulverized coal sample was be taken every 15 minutes from its pulverizer outlet. The pulverized coal samples were taken with a special cyclone sampler and put in jars or bags on which the time of the sample was noted. This allowed matching of the coal sulphur levels with the

SO2 levels.

At the beginning of each test the hopper under the cyclone flyash collectors was emptied. At the end of each test, ash samples were taken from the hopper under the Pratt Daniel flyash collectors and from the furnace bottom. Since most of the ash carried over, the samples from the Pratt Daniel hoppers were the main source of carbon carryover.

4 EXPERIMENTAL RESULTS

4.1 Operating Conditions

Operating temperatures were much higher from February 28 through March 4 than from March 11 through March 13. Slagging and defective soot blowers caused the high temperatures during the first of the two periods.

Tests were run February 28, March 1 and March 2 at 10 MW (half load for Unit No 2 but full load for the single lower burner) burning high sulphur test coal of a quality inferior to that of the base coal. The low ash fusion temperature and high ash content of the test coal caused severe slagging while the test coal was in use. As a consequence, furnace slagging combined with an undetected soot blower problem, caused furnace temperatures that were much higher than typical.

Because of the high temperatures, operation with both burners proved impractical until the furnace was deslagged. The unit was shut down after the March 4 tests to deslag and to investigate a suspected soot blower problem in the convective section. It was discovered that the diaphragm which operates the compressed air valve supplying the soot blowers had been deteriorating over a period of years. The soot blowers appeared to be operating normally, but they were inoperative. Flue gas temperatures dropped to levels below those observed during any of the previous tests, after the furnace was cleaned and soot blowers were

repaired.

Observation of the low temperatures on March 11 and March 12 convinced the operators that operation with 2 burners would be safe so tests were run at 17 MW, the highest load attainable given the weather, on March 13. Previously it had been thought that the high temperatures had been due in part to the flame pattern.

The air preheater bypass was closed throughout the February/March/87 test program.

4.2 Results - SO2 Emissions

The results of the flue gas measurements are given in Tables 1 and 2. All SO2 and NOx levels are corrected to 3% oxygen. In general, sulphur dioxide emissions were reduced more than 50% after adjustment for coal sulphur content with low Ca/S ratios, with the low sulphur base coal.

Addition of limestone at a 1.34 Ca/S ratio reduced sulphur dioxide emissions from 2163 ppm on 28 Feb (with no limestone) to 986 ppm on March 2, a reduction of 1177 ppm or 54.44%. Allowing for the fact that on Feb 28, the sulphur level in the coal was 3.15% compared with 2.91% on 2 Mar., the reduction becomes 50.66%. The load was 9.9 MW on Feb 28 and 11.8 MW on Mar 2.

In 1982 with a 2.6% sulphur coal, the SO2 emission level at half load without limestone averaged 2006 ppm. The March 2, 1987 SO2 level is 986 ppm or, after adjusting for different sulphur levels, a 56% reduction from the 1982 level. (In other words, after prorating the ppm of SO2 for the 1982 baseline level with the percent sulphur in the two coals so it reflects the same % sulphur in coal as the 1987 test, the ppm SO2 in 1987 were 56% that of 1982.) The March 2,1987 Ca/S ratio was 1.39.

Table 1

March 1987 Gagetown Tests, before blr. cleaning

	TEST	P2	P7	P9	P10	P11
	DATE	Feb28	Mar2	Mar3	Mar4	Mar4
	TIME Start	15.12	12.55	14.2	10.22	13.16
	End	-16.55	-14.28	-15.45	-11.48	-15.08
ctype		Test	Test	Base	Base	Base
I						
Ca/S MOLE RATIO		0	1.39	0	2.25	1.85
COMBINED FUEL EFFICIENCY%		78	82	82.9	83.6	83.4
*SO2 Absorption %		0	50.66	0	58.97	77.77
Calcium efficiency		0	.36511	0	.26158	.42078
I						
#PPM of SO2		2163	986	827	281	181
#PPM of NOx		492	391	347	276	261
I						
%Ash to Cyclone+Carryover		90	90	90	90	90
+% Carbon in Bottom Ash		7	2.21	6.82	4.88	5
+% CARBON IN CYCLONE ASH		33.86	10.41	72.66	20.32	17
Unburned C in Ash Loss %		3.86	1.66	2.11	1.03	1.12
I						
AH Outlet Temp. (C)		282	288	260	272	270.5
% O2 by Vol		6	3	2.9	2.4	2.7
Blr Output (MW)		9.9	11.8	9.6	10	10
H2 & H2O Loss (%)		4.57	4.41	4.18	4.2	4.2
Dry Gas Loss (%)		12.18	10.7	9.33	9.77	9.84
I						
Dry Flue Gas (kg/hr)		15910.	16385.	13108.	13507.	13638.
H2O in Flue Gas (kg/hr)		553.67	636.40	500.04	518.32	518.11
Total Air (kg/hr)		15412.	15770.	12646.	13005.	13142.
I						
Oil Flowrate (L/hr)		40	40	40	40	40
Oil (% Total Energy Input)		3.38	2.98	3.71	3.59	3.58
Limestone Feedrate (kg/hr)		0	222.7	0	97.95	96
KJ/kg Limestone		-725.0	9.1257	-725.0	-199.0	121.06
% CaCO3 in limestone		95	95	95	95	95
Coal Feedrate (kg/hr)		1536	1671	1191	1225	1236
KJ/kg Coal		28750.	30080.	33685.	33885.	33660.
I						
COAL ANALYSIS	Carbon	68.64	72.09	81.02	81.73	80.93
	Hydrogen	4.42	4.6	5.1	5.12	5.09
	Nitrogen	1.23	1.39	1.62	1.61	1.66
	Oxygen	7.55	6.46	6.04	5.98	6.43
	Sulphur	3.15	2.91	1.28	1.06	1.26
	Ash	10.93	9.64	3.31	3.02	3.13
	Moisture	4.08	2.91	1.63	1.48	1.5

* Emissions were compared to those without limestone added correcting for equivalent S contents

+ Carbon in coal only

Corrected to 3% O2

Table 2

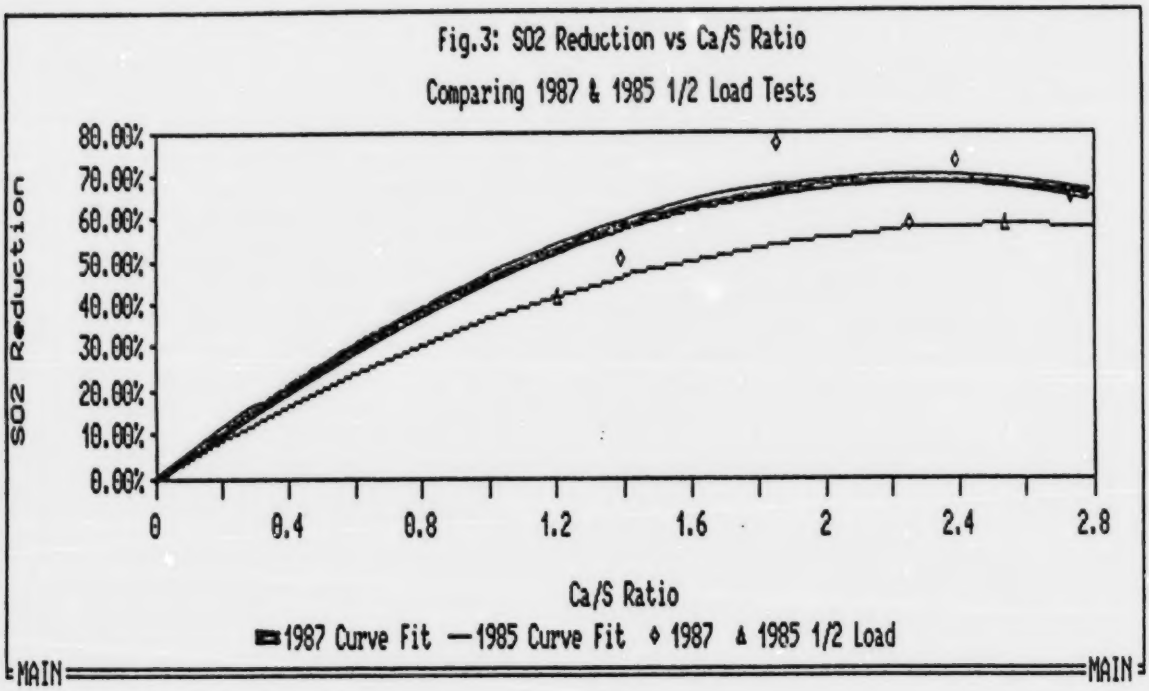
March 1987 Gagetown Tests, using base coal

	TEST	P13	P16a	P16b	P17	P19
	DATE	Mar11	Mar12	Mar12	Mar13	Mar13
	TIME Start	14.29	13.28	14.2	9.13	14.54
	End	-15.37	-14.2	-14.56	-10.4	-16.27
I						
I						
Ca/S MOLE RATIO		0	2.73	2.39	0	3.64
COMBINED FUEL EFFICIENCY%		86.7	86.9	87.1	88.5	88
*SO2 Absorption %		0	65.7	73.68	0	54.5
Calcium efficiency		0	.24110	.30858	0	.14991
I						
#PPM of SO2		764	227	276	784	357
#PPM of NOx		364	420	417	400	363
I						
%Ash to Cyclone+Carryover		90	90	90	90	90
+% Carbon in Bottom Ash		28.32	7.52	7.52	2	2
+% CARBON IN CYCLONE ASH		78.71	22.67	22.67	21.54	21.54
Unburned C in Ash Loss %		1.75	1.54	1.37	.47	.96
I						
AH Outlet Temp. (C)		186	169	170	177	177
% O2 by Vol		3	5.16	5.08	4.03	3.84
Blr Output (MW)		10.7	10.5	10.5	17.4	17
H2 & H2O Loss (%)		3.93	3.93	3.88	3.9	3.93
Dry Gas Loss (%)		6.29	6.33	6.33	6.29	6.23
I						
Dry Flue Gas (kg/hr)		14682.	16387.	16292.	25508.	24710.
H2O in Flue Gas (kg/hr)		551.53	548.94	541.02	895.71	883.11
Total Air (kg/hr)		14152.	15850.	15752.	24628.	23827.
I						
Oil Flowrate (L/hr)		40	40	40	65	65
Oil (% Total Energy Input)		3.48	3.55	3.56	3.54	3.62
Limestone Feedrate (kg/hr.)		0	120	123.4	0	237.15
KJ/kg Limestone		-725.0	-240.2	-104.6	-725.0	-423.6
% CaCO3 in limestone		95	95	95	95	95
Coal Feedrate (kg/hr)		1268	1275	1249	2013	1975
KJ/kg Coal		33812.	32922.	33509.	33932.	33969.
I						
COAL ANALYSIS	Carbon	81.324	79.263	80.66	81.375	81.47
	Hydrogen	5.0403	4.9446	4.96	5.0417	5.089
	Nitrogen	1.5755	1.6879	1.5	1.6722	1.6528
	Oxygen	6.551	6.5035	6.8	6.2624	6.141
	Sulphur	1.1368	1.0326	1.24	1.1604	.9861
	Ash	2.4625	4.4482	2.72	2.5186	2.801
	Moisture	1.91	2.12	2.12	1.97	1.86

* Emissions were compared to those without limestone added correcting for equivalent S contents

+ Carbon in coal only

Corrected to 3% O2



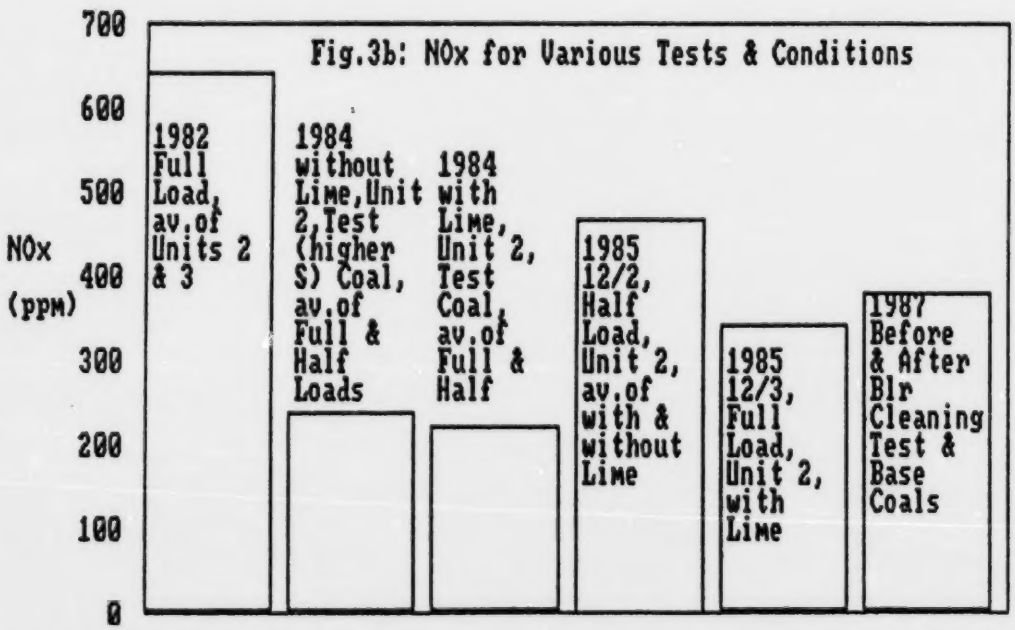


Fig.3b: NOx for Various Tests & Conditions
NOx (ppm)
700
600
500
400
300
200
100
0
1982 Full Load, av.of Units 2 & 3
1984 without Lime,Unit 2,Test (higher S) Coal, av.of Full & Half Loads
1984 with Lime, Unit 2, Test Coal, av.of Full & Half
1985 12/2, Half Load, Unit 2, av.of with & without Lime
1985 12/3, Full Load, Unit 2, with Lime
1987 Before & After Blr Cleaning Test & Base Coals

Tests with different conditions were only averaged if the results were similar.

To develop a basis of comparison, Unit 2 was run without limestone on March 3. The SO2 level without limestone on Mar 3. was 827 ppm using base coal with 1.28% sulphur. With a Ca/s ratio of 2.25, a level of 281 ppm (a 58.97% reduction after allowing for coal S) was achieved the morning of Mar 4. The SO2 level was 181 ppm (77.7% reduction after allowing for coal S) in the afternoon of Mar 4 with a Ca/S ratio of 1.85. The load was 9.6 MW on Mar 3 and 10 MW all day Mar 4.

After the boiler had been deslagged and the soot blowers repaired, Unit No 2 unit was run at 10.7 MW on March 11 without limestone to provide a baseline. The SO2 emission level was 764 ppm with 1.137 % sulphur coal. On March 12 two tests were run. For the first, the coal sulphur was 1.03%, the Ca/S ratio was 2.73 and the SO2 emission level, 227 (a reduction of 65.7% after allowing for the difference in coal sulphur). For the second test March 12 the coal sulphur was 1.24%, the Ca/S ratio 2.39 and the SO2 emission level 276 ppm or 73.68% below the March 11 level after allowing for the difference in coal sulphur levels.

On March 13, a baseline test was run without limestone with 1.16% sulphur coal at 17 MW. The SO2 emission level was 784 ppm. A further test was run with 0.986% sulphur coal and a Ca/S ratio of 3.65. The SO2 emission level was 357 ppm, a 54.5% reduction after allowing for the decline in coal sulphur between the baseline and second tests.

Figure 3 on the previous page shows that the 1987 tests achieved a somewhat higher SO2 reduction than the 1985 tests.

4.3 Results - NOx Emissions

The changes which led to the improvement in unburned carbon loss impaired the NOx reduction capability of the burner. It may be possible to improve this via further experimentation with secondary/tertiary air ratios.

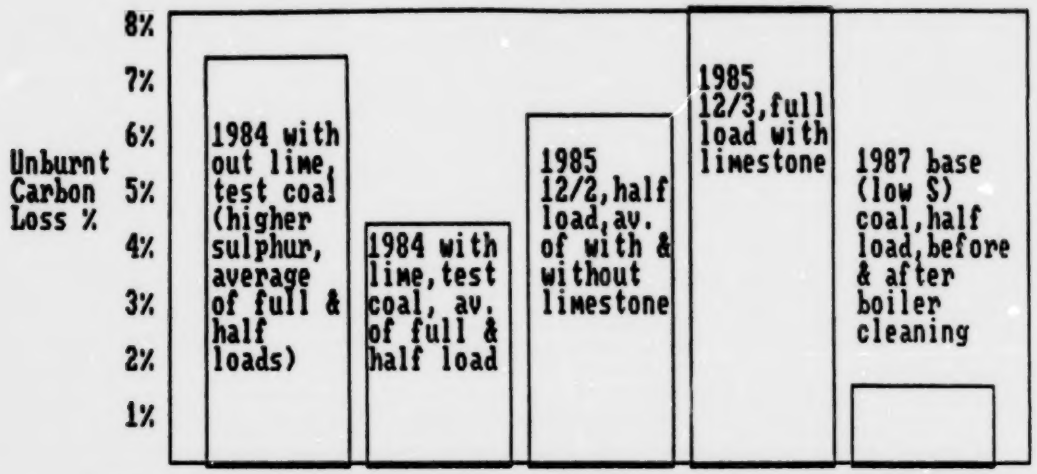

Unburnt Carbon Loss %
8%
7%
6%
5%
4%
3%
2%
1%
1984 with out lime, test coal (higher sulphur, average of full & half loads)
1984 with lime, test coal, av. of full & half load
1985 12/2, half load, av. of with & without limestone
1985 12/3, full load with limestone
1987 base (low S) coal, half load, before & after boiler cleaning

Figure 4: Unburnt Carbon losses for Various Test & Conditions
Tests with different conditions were av. only if results were similar

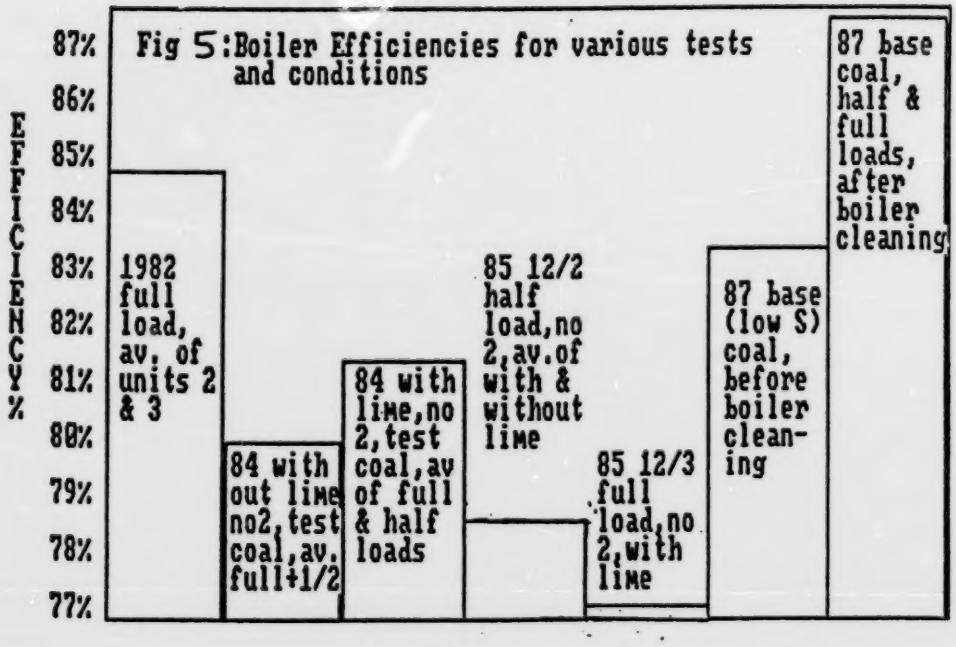


Fig 5: Boiler Efficiencies for various tests and conditions
EFFICIENCY %
87%
86%
85%
84%
83%
82%
81%
80%
79%
78%
77%
1982 full load, av. of units 2 & 3
84 with out lime no2, test coal, av. full+1/2
84 with lime, no 2, test coal, av of full & half loads
85 12/2 half load, no 2, av. of with & without lime
85 12/3 full load, no 2, with lime
87 base (low S) coal, before boiler clean-ing
87 base coal, half & full loads, after boiler cleaning

Tests with different conditions were only averaged if the results were similar.

Nitrogen oxide levels at half load during the 1982 baseline tests with the old burners were in the 300 to 420 ppm range after correction to 3% oxygen. The lowest levels during the 1987 tests were 276 ppm and 261 ppm on March 4. For all other tests they were at levels were 347 ppm or more.

On March 13/87 the NOx levels were 400 and 363 when the load was 17 MW. This compares with levels in the 590 to 720 range for 4 out of 5 tests at full load in 1982. For one of the 1982 tests the level was 480 ppm.

Figure 3b (two pages previous) shows little difference between 1987 NOx levels and those of previous tests. In spite of lower flue gas temperatures, the NOx levels after the 1987 boiler cleaning were not lower than 1987 levels before cleaning.

4.4 Results - Carbon Burnout

Losses due to unburned carbon in the ash are compared in Fig. 4 on the next page. Tables 1 and 2 (Four & three pages previous) show % carbon in both the fly ash and the bottom ash. Since most of the ash passed through and was collected by the cyclone, ash data is significant as is the unburned carbon loss estimate (the reduction on boiler efficiency due to unburned carbon). The reduction in efficiency was in the 0.47% to 2.11% except for 28 February when it was 3.86%. For the tests after the unit was cleaned it was in the 0.47 to 1.75% range. This compares with reductions in boiler efficiency of 4% and more for the 1984 and 1984 tests with the Steimueller burner.

4.5 Temperatures and Flue Gas Losses

As noted previously, flue gas temperatures were excessive before deslagging and sootblower repairs. After the boiler was cleaned the temperature after the air preheater (the last heat recovery device) was in the 167 C to 186 C range. This compares with flue

gas temperatures in the 181 C to 206 C for half load tests in 1984 and the 207 C to 229 C for half load tests in 1985. During the 1982 tests, temperatures leaving the air preheater were in the 182 to 186 C range. In comparing temperatures leaving the air preheater with those during the 1984 and 1985 tests it should be noted that during those tests there was some doubt about the position of the air preheater bypass.

On March 13/87 at 17 MW the flue gas temperature was 177 C, for the full load tests. At loads in the 15 to 20 MW range in 1984 and the 1985 flue gas temps. were in the 223 C to 264 C range.

4.6 Results - Primary Air Flow

The primary air flow was measured in a straight vertical run of 0.32 meter (1.01 ft) circular duct between the air preheater and the pulverizer. The point of measurement for the lower burner is far enough away from connections, bends, the flow measuring device, etc. that a good measurement can be obtained. At this point the estimated primary air flow was kept nearly constant. Using representative measurements the estimated flow was 25.7 kg/minute or 1543.12 kg/hr at 225 C and 10 MW.

There is provision for adding either room air for tempering or furnace gas for heating between this measurement point and the pulverizer inlet. The room air connection was shut off and covered with canvas. The mixture after the gas connection was analyzed and found to contain 19.9% oxygen so there was very little flue gas. It was not possible to measure the gas flow directly.

4.7 Results - Secondary/ Tertiary/Core Air Flow

The estimated secondary/tertiary/core air flow at 10 MW for the lower burner is 11,000 kg/hr (24,250 lb/hr). The core air flow was negligible. Flow measurement conditions for secondary air were much less satisfactory than for primary air to the lower

burner.

It was not possible to measure tertiary and secondary air flows separately because they are separated only at the point where the common duct is connected to the windbox. The tertiary air windbox pressure, measured with a water manometer throughout the tests, was 3 to 4 mm of water most of the time, thus indicating a low tertiary air flow. The corresponding secondary air windbox pressure was several centimeters of water.

4.7 Results - Boiler Efficiency

Boiler efficiencies are compared in Fig. 4 (three pages previous). On March 13 with a 17 MW load the boiler efficiency was 88 %, and the air preheater outlet was temperature 177 C at 4% oxygen. The loss due to carbon in the ash was about 0.7%. This is higher than efficiencies achieved in any previous tests including the 1982 baseline tests. The half load efficiencies with the clean boiler (March 11 and March 12) were approximately 87%. On March 2, 3 and 4 when the soot blowers were not working properly and the boilers were badly slagged the efficiency was about 83%.

5 DISCUSSION OF RESULTS

The results of the tests with the badly slagged boiler are more representative of conditions in a larger, multi-burner boiler with higher furnace temperatures. Apparently in some large boilers furnace temperatures are high enough to cause dead burning even when the limestone does not pass through the burner tip.

Although, the largest reduction in SOx emissions was achieved on March 4 when the furnace exit temperatures were high. The burner vortex appeared to draw the tertiary air carrying the limestone into the flame much more effectively which probably accounts for the improved SOx absorption.

The impairment in NOx reduction capability is probably due to the increased secondary air flow at the burner tip. Whether or not this trade-off between good combustion and NOx reduction can be resolved remains to be determined.

6 CONCLUSIONS

Results in terms of SOx reduction, combustion stability, boiler operation and boiler efficiency were satisfactory. The carbon carryover was marginally acceptable and might be improved with further burner modification. NOx reduction was not as low as desired but the results suggest that further modification and adjustment may achieve more NOx reduction while retaining carbon burnout at a satisfactory level.

The limestone system is now operating satisfactorily, although the counter inside the panel can not be read during operation if the door is closed. The panel cannot be opened when the boiler is running without causing a trip.

The boiler operating panel is not enclosed and coal dust reduces the reliability of the controls. This appears to a potentially

serious problem.

Increasing the area of the coal annulus and reducing the primary air volume to reduce the velocity of the coal particles leaving the coal gun, helped improve ignition as has the improved vortex. The improved vortex is apparently due to adjustment of swirl and elimination of the oil burner vanes to prevent flame impingement on the furnace walls.

7 RECOMMENDATIONS

The ductwork should be modified to allow measurement of tertiary air flow, if a serious attempt is to be made to improve NOx reduction. Otherwise the burners appear to operate satisfactorily.

If the NOx reduction capability of the burners is to be improved, an NOX monitor should be installed during the adjustment process.

To improve reliability of the system as a whole and to reduce the risk of incorrect readings, the control panel should be enclosed and the enclosure pressurized and air conditioned. The air supply should be filtered and cooled. A glass or plastic enclosure would not be expensive. It would improve working conditions and reduce control panel maintenance costs.

The supplier or the limestone system should be contacted to determine whether the system can be adjusted to operate over a lower range of limestone feedrates. During all of the 1987 tests the feeder was set at the lower end of the range. The tests with low sulphur coal required a setting so low that the system tended to be unstable.

REFERENCES - G. A. Robb Associates, "CFB Gagetown Low NOx/SOx Program", Tests conducted 1982, 1984 & 1985, March 1986, DSS cont no 0SQ83-00128

4.2.1 Copulverizer System for 1982 tests

The system for copulverizing limestone and coal was designed by F. W. Pollit, who was heating plant superintendent in 1982. It consisted of a small hopper, a conical orifice and a duct leading to an existing opening just below the rotary coal feeder to each pulverizer.

Granular limestone in bags was piled near the pulverizers and fed to the hopper manually. The orifice was calibrated during a preliminary run. The number of bags per hour provided a check on the limestone feedrate.

During the trial runs pieces of paper and refuse in the limestone plugged the orifice from time to time. This problem was solved by using a coarse wire mesh on the top of the hopper to screen the granular limestone.

The low cost temporary system proved to be satisfactory for developing a basis for comparing the results of copulverization with those with injection of lime dust via the tertiary air ports.

TEST RESULTS

Table 1 Coal Analysis

	COAL % BY WT.							HHV	
	C	H	S	N	O	Ash	Water	BTU/lb	KJ/kg
1982 Baseline Tests	75.2%	4.8%	2.6%	1.4%	6.2%	9.4%	1.5%	14303	33266

Table 2 March 1982 Baseline Test Results

The following table summarizes the baseline test results including boiler efficiency and mole ratio calculations for full load tests:

TEST RESULTS

DAY	HOUR	UNIT	LOAD MW	% O2 <***> (+++)	NOx <mg/MJ> (ppm)	SO2 <mg/MJ> (ppm)	CO ppm	BLR EFF% *	GAS TEMP ***	Ca/S MOLE *
26	845-1145	2	20	<3.6> (3.6)	<296> (480)	<1665> (1920)	18	85.6	211 C	0
26	1442—1628	2	10	<3.8> (3.8)	(300)	(2100)	**			0
27	930-1230	2	9	<4.0> (4.0)	(370)	(1930)	**			0
28	845-1145	3	20.6	<4.3> (6.0)	<360> (590)	<1620> (1970)	16	84.06	240 C	0
28	1545—1600	3	10.5	(6.2)	(420)	(1990)	26			0
29	800-1100	3	18.58	<4.74> (6.5)	<469> (720)	<1158> (1280)	1.5	82.47	260 C	3.25
29	1315—1615	3	8.5	(7.2)	(420)	(1200)	18			N.A.
30	900-1100	3	19.68	<4.51> (6.1)	<429> (660)	<1129> (1250)	1.7	82.77	256 C	3.13
30	1405—1550	3	19.96	<4.54> (6.3)	<459> (750)	<1131> (1330)	1.1	82.19	269 C	2.72

** CO fluctuated too much to take proper average readings.
*** Sampling point: Where the flue gas exits the air heater.
NOx, SO2 and CO readings are corrected to 3% oxygen.
+++ Sampling point: Duct from the test boiler, just before the settling chamber.
Note: From March 26 to 27, the tests were done on unit 2.
After and including the 28th, unit 3 was used.
Test from the 29th through the 30th, involved limestone.

Environment Canada / Environnement Canada
Conservation and Protection / Conservation et Protection

Pollution Measurement Division
Technology Development & Technical Services Branch
River Road Environmental Technology Centre
OTTAWA, Ontario. K1A 0E7

Your file / Votre référence

Our file / Notre référence 4030-7-1

May 7, 1987

Mr. Gordon Robb
G.A. Robb Associates
1855 Beattie Avenue
OTTAWA, Ontario. K1H 5R7

Dear Gordon:

RE: CFB GAGETOWN PROGRAM

Enclosed please find the gas concentration data for the recent CFB Gagetown testing program. I have highlighted the averages for each test. Please note that the concenterations of SO2, NOx, THC, CO and CO2 have been corrected to 3% O2.

We would appreciate receiving copies of any analytical data (coal, ash, etc.) that you receive.

Yours very truly

R B McCaig

for Brian D. Williams, Supervisor
Quality Assurance and Continuous
Source Monitoring Unit
Source Measurement Section
(613) 998-4772

c.c. R.B. McCaig/ D. Cianciarelli

Canada

Rk2S

TEST COAL,50% LOAD,NO LIMESTONE

RUN No	SO2	NOx	THC	CO	O2	CO2
P-1	2158	460	2.1	130	4.94	15.83
	2151	483	2.3	131	5.35	15.84
	2170	448	2.2	130	4.68	15.78
	2185	456	2.2	132	4.89	15.83
	2116	457	2.1	135	5.02	15.98
	2110	419	1.9	132	4.18	15.91
	2124	438	2.0	133	4.51	16.00
	2145	452	2.1	132	4.80	15.88

SO_2 NOx THC
CO CO_2
corrected to 3% O_2

TEST COAL,50% LOAD,NO LIMESTONE

RUN No	SO2	NOx	THC	CO	O2	CO2
P-2	2100	543	2.0	162	6.83	16.17
Feb.28,1987	2166	477	1.7	140	5.17	16.08
15:12-16:55	2150	497	1.6	138	5.63	16.04
	2182	490	1.8	145	5.69	15.96
	2191	458	1.7	137	4.73	15.84
	2176	477	1.6	140	5.15	15.79
	2179	501	1.8	145	5.75	15.95
	2163	492	1.7	144	5.56	15.97

TEST COAL,75% LOAD,NO LIMESTONE

RUN No	SO2	NOx	THC	CO	O2	CO2
P-3	2110	460	2.2	106	4.32	15.29
	2093	459	2.1	108	4.20	15.39
	2107	459	2.3	111	4.26	15.47
	2100	477	2.3	109	4.57	15.34
	2121	428	2.1	103	3.98	15.41
	2110	432	2.1	107	4.13	15.59
	2107	453	2.2	107	4.24	15.42

TEST COAL,50% LOAD,WITH LIMESTONE

RUN No	SO2	NOx	THC	CO	O2	CO2
P-4	919	405	1.1	105	4.55	16.40
	910	419	1.2	107	4.89	16.49
	943	399	1.2	93	4.38	16.21
	926	426	1.1	96	4.98	15.48
	857	409	1.2	99	4.80	15.19
	870	407	1.2	96	4.66	14.97
	904	411	1.2	99	4.71	15.79

TEST COAL,50% LOAD,WITH LIMESTONE(2.5:1)

RUN No	SO2	NOx	THC	CO	O2	CO2
P-5	1044	346	1.5	107	3.20	15.10
	1008	392	1.5	109	4.01	15.90
	948	409	1.5	103	4.23	14.94
	954	403	1.7	104	4.08	15.37
	932	402	1.7	97	4.16	16.73
	930	388	1.7	91	3.83	16.54
	969	390	1.6	102	3.92	15.76

TEST COAL,50% LOAD,WITH LIMESTONE(2.0:1)

RUN No	SO2	NOx	THC	CO	O2	CO2
	955	384	2.7	93	3.71	16.53
	956	397	1.8	93	3.80	16.44
	948	394	1.7	93	3.72	16.69
	953	392	2.1	93	3.74	16.55

TEST COAL,50% LOAD,WITH LIMESTONE(3.0:1)

RUN No	SO2	NOx	THC	CO	O2	CO2
	874	357	1.6	93	3.37	16.89
	851	361	1.5	95	3.22	16.85
	862	351	1.5	94	3.04	16.73
	862	357	1.6	94	3.21	16.82

TEST COAL,50% LOAD,WITH LIMESTONE(<2.0:1)

RUN No	SO2	NOx	THC	CO	O2	CO2
P-6	764	468	2.5	104	5.78	16.07
	796	472	2.5	106	5.88	16.28
	812	484	2.7	108	6.10	15.88
	831	507	2.9	108	6.71	15.86
	834	477	2.8	103	5.98	15.54
	899	415	2.2	99	4.52	15.28
	823	471	2.6	105	5.83	15.82

TEST COAL,50% LOAD,WITH LIMESTONE(<2.0:1)

RUN No	SO2	NOx	THC	CO	O2	CO2
P-7	998	416	1.7	91	4.50	16.10
Mar. 2,1987	975	397	1.7	90	4.22	16.14
12:55-14:28	981	380	1.5	89	3.87	15.92
	989	372	1.7	93	3.99	15.95

	986	391	1.7	91	4.15	16.03

POST-LIMESTONE INJECTION BASELINE (50%)

RUN No	SO2	NOx	THC	CO	O2	CO2
	1903	439	1.8	81	4.63	15.52
	1916	452	1.8	84	4.67	15.53
	1928	476	1.8	85	5.11	15.47
	1942	489	2.0	90	5.31	15.47
	1922	464	1.8	85	4.93	15.50

BASE COAL,50% LOAD,NO LIMESTONE

RUN No	SO2	NOx	THC	CO	O2	CO2
P-8	827	343	3.0	140	4.69	15.64
	858	340	3.1	155	4.57	15.59
	860	349	3.2	158	4.66	15.40
	847	345	3.2	156	4.50	15.39
	864	369	3.1	147	4.86	15.32
	843	357	2.9	157	4.64	15.21
	850	351	3.1	152	4.65	15.42

BASE COAL,50% LOAD,NO LIMESTONE

RUN No	SO2	NOx	THC	CO	O2	CO2
P-9	840	332	2.6	145	4.18	15.96
Mar.3,1987	827	355	2.7	148	4.48	15.99
14:20-15:45	824	362	2.5	141	4.61	16.02
	829	365	2.3	149	4.71	16.09
	823	335	2.2	156	4.37	15.94
	819	335	2.3	155	4.43	16.02
	827	347	2.4	149	4.46	16.00

) BASE COAL,50% LOAD, LIMESTONE INJECTION(2.

RUN No	SO2	NOx	THC	CO	O2	CO2
P-10	261	311	2.3	142	4.85	16.22
Mar.4,1987	286	255	2.3	178	4.10	16.13
10:22-11:48	283	256	2.3	154	4.21	16.19
	290	254	2.3	152	4.22	16.18
	279	256	2.1	148	4.24	16.15
	285	249	2.2	147	4.15	16.01
	281	276	2.3	154	4.30	16.15

) BASE COAL,50% LOAD, LIMESTONE INJECTION(2.

RUN No	SO2	NOx	THC	CO	O2	CO2
P-11	180	276	2.0	125	4.61	16.69
	161	274	1.9	130	4.62	16.69
Mar.4,1987	175	245	2.4	130	4.20	16.66
13:16-15:08	188	254	1.9	133	4.18	16.79
	195	247	1.8	133	4.12	16.82
	187	271	1.9	128	4.67	16.79
	181	261	2.0	130	4.40	16.74

BASE COAL,50% LOAD,NO LIMESTONE*

RUN No	SO2	NOx	THC	CO	O2	CO2
P-12	837	386	4.6	102	6.81	15.80
	850	344	4.4	102	6.11	15.71
	834	349	4.0	103	6.16	15.80
	816	368	4.1	102	6.65	15.97
	816	323	3.9	95	5.70	15.92
	807	321	4.2	94	5.69	15.76
	827	348	4.2	100	6.19	15.83

BASE COAL,50% LOAD,NO LIMESTONE*

RUN No	SO2	NOx	THC	CO	O2	CO2
P-13	760	351	1.7	49	3.11	15.84
Mar.11,1987	769	365	1.9	47	3.41	15.88
14:29-15:37	763	346	1.8	52	3.02	15.72
	764	393	1.9	49	4.10	15.82
	764	364	1.8	49	3.41	15.82

BASE COAL,50% LOAD,NO LIMESTONE*

RUN No	SO2	NOx	THC	CO	O2	CO2
P-14	772	527	5.9	91	6.53	16.47
	765	498	4.7	80	6.14	16.32
	759	500	4.1	79	5.95	16.08
	749	510	3.6	84	6.17	16.00
	761	509	4.6	83	6.20	16.22

BASE COAL,50% LOAD,WITH LIMESTONE(2.5)*

RUN No	SO2	NOx	THC	CO	O2	CO2
P-15	210	447	2.1	78	6.24	16.04
	205	420	2.0	76	5.89	16.04
	199	436	2.1	81	6.24	16.06
	202	409	1.9	73	5.72	16.00
	198	407	1.9	74	5.83	16.00
	210	389	1.7	73	5.45	16.03

	204	433	2.0	76	5.90	16.03

BASE COAL,50% LOAD,WITH LIMESTONE(2.5)*

RUN No	SO2	NOx	THC	CO	O2	CO2
P-16	241	437	2.4	83	5.95	16.63
	237	421	2.2	79	5.73	16.63
P16a: Mar.12,87	227	402	2.1	73	5.35	16.66
13:28-14:22	222	414	2.0	76	5.59	16.77
P16b: Mar.12,87	222	407	2.0	73	5.42	16.74
14:20-14:56	214	431	2.2	82	5.98	16.58
	227	419	2.1	77	5.67	16.67

* BASE COAL,50% LOAD,WITH LIMESTONE(LOW RATE

RUN No	SO2	NOx	THC	CO	O2	CO2
SCREEN	274	433	2.0	71	5.94	16.66
	276	447	2.1	78	6.24	16.69
	280	461	2.2	82	6.45	16.69
	275	447	2.1	77	6.17	16.66
	275	445	1.9	79	5.99	16.74
	276	447	2.1	77	6.16	16.69

POST TEST WITHOUT LIMESTONE

RUN No	SO2	NOx	THC	CO	O2	CO2
	720	458	1.7	66	5.72	16.32

BASE COAL,87.5%,NO LIMESTONE*

RUN No	SO2	NOx	THC	CO	O2	CO2
P-17	777	399	1.2	31	4.38	15.73
Mar.13,1987	784	405	1.2	32	4.54	15.81
9:13-10:40	790	406	1.1	34	4.81	15.82
	788	401	1.0	33	4.64	15.78
	790	400	1.1	33	4.64	15.72
	774	392	1.4	31	4.37	15.65
	784	400	1.2	33	4.56	15.75

BASE COAL,87.5%,WITH LIMESTONE(2.5)*

RUN No	SO2	NOx	THC	CO	O2	CO2
P-18	368	403	1.4	34	5.00	16.31
	373	384	1.2	34	4.76	16.33
	356	378	1.1	37	4.76	16.42
	353	398	1.1	37	4.98	16.43
	352	399	1.1	36	4.97	16.36

	360	392	1.2	36	4.89	16.37

BASE COAL,87.5%,WITH LIMESTONE(2.5)*

RUN No	SO2	NOx	THC	CO	O2	CO2
P-19	375	353	0.6	30	3.83	16.25
Mar.13,1987	357	368	0.8	34	4.36	16.17
14:54-16:27	360	355	0.6	34	4.13	16.09
	357	362	0.6	33	4.19	16.12
	348	372	0.7	34	4.38	16.16
	348	369	0.6	32	4.27	15.89
	357	363	0.7	33	4.19	16.11

BASE COAL,19.5 MW,~2.2

RUN No	SO2	NOx	THC	CO	O2	CO2
	394	389	0.8	27	3.88	15.93

BASE COAL,16 MW,~2.2(16%)

RUN No	SO2	NOx	THC	CO	O2	CO2
	353	503	ERR	94	8.73	16.75

BASE COAL,17 MW,(16%)

RUN No	SO2	NOx	THC	CO	O2	CO2
	366	424	ERR	43	5.58	16.90

BASE COAL,17 MW,(12%)

RUN No	SO2	NOx	THC	CO	O2	CO2
	363	431	ERR	43	5.8	16.96

DATE [Test Coal]	28 FEB 87	28 FEB 87	28 FEB 87	28 FEB 87	1 MAR 87	1 MAR 87	1 MAR 87	1 MAR 87	TEST COAL
TIME	11.30 AM	13:10	15:15	16:02	13:30	14:45	16.50	17.40	
MW BD	10	10.2	8.5	10	10.5	10.7	11	11.5	
WATER FLOW BD X	45	45	47	48	48	48	49	48	
AIR FLOW BD X	32	32	32	32.5	33	33.5	34.5	35	
GAS IN AH BD 0 TO 400C	400	400	400	400	400*	400*	400*	400*	
GAS IN AH GAR					414				
GAS OUT AH BD 0 TO 400C	280	282	280	284	282	297	300	298	
GAS OUT AH GAR C	281				290			289	
AIR IN AH BD 0 TO 400C	23	23	23	23	20	19	20	20	
AIR IN AH GAR	26				24				
AIR OUT AH BD 0 TO 400C	255	259	255	255	250	250	246	245	
AIR IN AH GAR	250				245				
WATER IN 0 TO 200C	147	148	148	148	180	179	179	175	
WATER OUT 0 TO 200C	180				146	145	144	140	
AH BYPASS 0 TO 100X	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	
XOXYGEN BOARD MOSTTIME	3.9	3.1	4	3.6	3.2	4.1	2.4	3	
XOXYGEN GAR DIF 1.2X	5.2	4.3	5.2	5.3	4.5		3.1	3.8	
X CO GAR	0.03	0.01							
LOWER BURNER TEMP COAL/AIR 0 TO 200C	97	100	98	100	95		95		
OIL FLOW					SMW				
SEC, TERT, CORE AIR FLOW MM	62	62	62.5	63.5	65	65.2			
PRIMARY AIR FLOW MANO	24	24	23	23	21	22	25	25	
TERT WINDBOX MM WG	NIL	NIL	NIL	NIL		SMM			
LOWER BURNER POSN CORE AIR									
POSN SEC AIR	66	66	66	68	67	67	72	72	
POSN TERT AIR	63	63	66	66					
EXHAUSTER OUT PRES					1.5 KPA	1.5 KPA	1.5 KPA	1.5 KPA	
POSN PRIM AIR									
POSN COAL FEEDER									
POSN EXHAUSTER									
POSN OIL FLOW									
SWIRL	122	122	122	122	125 MM	125 MM	125 MM	125 MM	
LIMESTONE FEEDER X					28	25	28	28	28
TIME					13:36	14:43	14:57	16:47	17:46
LIMESTONE COUNTER START					6996	10248	11000	16859	20118
TIME COUNT (hr)					13.60	14.72	14.95	16.78	17.77
LIMESTONE FEEDRATE (KG/HR)						291.2	322.3	319.6	331.4

1987

DATE TEST COAL >	2 MAR/87	2 MAR 87	2 MAR 87	2 MAR 87	Base Coal>	3 MAR 87	3 MAR 87	3 MAR 87	3 MAR 87
TIME	10:00	10:45 AM	13:00	14:00		11:15	12:05	14:35	15:35
MW BD	11	10.3	11	11		9.8	9.7	9.5	9.6
WATER FLOW BD	44	45	44	44		42	42	42	41
AIR FLOW BD	36	36	36	36		28	28	28	28
GAS IN AH BD O TO 400C	400+	400+	400+	400+		385	391	392	397
GAS IN AH GAR	420	415	415						
GAS OUT AH BD O TO 400C	290	288	286	292		260	260	259	260
GAS OUT AH GAR		286				505F		508F	
AIR IN AH BD O TO 400C	20	20	20	20		20	20	20	20
AIR IN AH GAR	75		80			80		80	
AIR OUT AH BD O TO 400C	245	240	243	250		255	250	250	250
AIR IN AH GAR		237							
WATER IN O TO 200C	179	174	180	181		176	178	179	180
WATER OUT O TO 200C	141	139	140	140		142	141	144	144
AH BYPASS O TO 100%	Closed	CLOSED	CLOSED	CLOSED		Closed	Closed	Closed	Closed
% OXYGEN BOARD	4	1.85	2.7	2		3.0	3.5	2.6	2.85
% OXYGEN GAR	5.2	3.2	4.6	3.8		4.6	5.4	3.2	4.2
% CO		0.02	0.02				0.02	0.02	0.02
Coal Feeder Lever							7		7
LOWER BURNER V									
TEMP COAL/AIR O TO 200C							85		95
OIL FLOW	.5	.5 MW	.5 MW	.5 MW		.5MW	.5MW	0.5	0.5
SEC, TERT, CORE AIR FLOW	71	71	71	70		54	54	55	53
PRIMARY AIR FLOW MANO	28	28	27	26.5		20	20	19	19.5
TERT WINDBOX MM WG		8MM	8MM	8MM					
LOWER BURNER POSN CORE AIR									
POSN SEC AIR	80	80	80	80		60	60	60	60
POSN TERT AIR	76	76	76	76		57	57	57	57
POSN PRIM AIR	30	30	30	30		23	23	23	23
POSN COAL FEEDER						80	80	80	80
EXHAUSTER OUT PRES kPA		1.7	1.7	1.65		1.2 kPa		1.2	1.3
POSN EXHAUSTER									
POSN OIL FLOW									
SWIRL	125mm	125 MM	125 MM	125 MM		125mm			
LIMESTONE FEEDER %	18	18	18	18	18				
TIME COUNT START	09:57	10:35	11:08	12:58	14:19				
LIMESTONE COUNTER START	12743	26111	27270	31258	34265				
TIME COUNT (hr)	9.95	10.58	11.13	12.97	14.32				
LIMESTONE FEEDRATE Kg/hr		?	210.7	217.5	222.7				

1987

1987

DATE (BASE COAL)	04 Mar 87	04 Mar 87	04 Mar 87	04 Mar 87	04 Mar 87			
TIME	10:25	11:00	13:30	14:30	15:30			
MJ BD	9.8	10.2	10	9.9	9.9			
WATER FLOW BD	38	38	37	37				
AIR FLOW BD	27	28	28	28				
GAS IN AH BD 0 TO 400C	>400	>400	400	400	399			
GAS IN AH GAR								
GAS OUT AH BD 0 TO 400C	273	271	270	271	271			
GAS OUT AH GAR	526 F							
AIR IN AH BD 0 TO 400C	20	20	20	18	19			
AIR IN AH GAR	78 F							
AIR OUT AH BD 0 TO 400C	259	252	246	244	242			
AIR OUT AH GAR								
WATER IN 0 TO 200C	180	180	184	186				
WATER OUT 0 TO 200C	140	140	144	146				
AH BYPASS 0 TO 100%	Closed	Closed	Closed	Closed	Closed			
% OXYGEN BOARD	2.3	2.3	2.1	2.2	4			
% OXYGEN GAR	3.7	3.6	3.3	4				
% CO	0.02	0.02	0.01	0.02				
LOWER BURNER U								
TEMP COAL/AIR 0 TO 200C	103	103		102				
OIL FLOW (MJ)	<0.5	<0.5	<0.5	<0.5	<0.5			
SEC, TERT, CORE AIR FLOW	51	53	54	54	57			
PRIMARY AIR FLOW MANO	22	22	22	21	23			
TERT WINDBOX MM UG								
LOWER BURNER POSN CORE AIR								
POSN SEC AIR	61	61	61	61	61			
POSN TERT AIR	58	57	72	72	72			
POSN PRIM AIR	24	25	25	25	25			
POSN COAL FEEDER	80		79	79	78			
EXHAUSTER OUT PRES kPA	1.15	1.1	1.1	1.2				
POSN EXHAUSTER								
POSN OIL FLOW								
SWIREL MM	125	125	125	125				
LIMESTONE FEEDER %	8	8	8	8	8	6	6	6
TIME	10:20	11:00	11:43	13:18	15:00	15:45	15:55	16:04
LIMESTONE COUNTER	35842	36495	37197	40323	41948	42631	42743	42839
TIME COUNT (hr)	10.33333	11	11.72	13.30	15.00	15.75	15.92	16.07
LIMESTONE FEEDRATE Kg/hr		97.95	97.95		95.59		67.20	64.00

BASE COAL	Soot blowers repaired and operating well by noon				BASE COAL						
DATE Tests run in morning	11 MAR 87	11 MAR 87	11 MAR 87	11 MAR 87	12 MAR 87	12 MAR 87	12 MAR 87	12 MAR 87	12 MAR 87	12 MAR	12 MAR
TIME but not used	14:30	15:30	17:30	18:20	10:45	11:20	12:00	13:30	14:30	15:00	
MW BD	10	10	10.2	10	10.5	10.5	10.6	10.5	11		
WATER FLOW BD	47	47			43	44	44	44.2	44.1		
AIR FLOW BD	35	35	32	32	32	32	32	31.8	31		
GAS IN AH BD O TO 400C	310	310	285	290	300	300	310	290	298		
GAS IN AH GAR											
GAS OUT AH BD O TO 400C	190	194	175	180	195	195	200	190	190		
GAS OUT AH GAR	181	185	176	181	185	188	195	181	185		
AIR IN AH BD O TO 400C	20	20	20	20	20	20	20	20	20		
AIR IN AH GAR	25	25	25	25	24	24	24	26	26		
AIR OUT AH BD O TO 400C	180	181	170	175	182	185	190	180	182		
AIR IN AH GAR											
WATER OUT O TO 200C	176	179	181	179	179	178	178	180	180		
WATER IN O TO 200C	146	146	146	146	140	140	140	144	144		
AH BYPASS O TO 100%	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED	CLOSED		
% OXYGEN BOARD			5	4.4	4.6	4.6	4.5	5	5		
% OXYGEN GAR	3.5?	3.5?	5.5	4.4	5.2	5.3	5.1	5.4	5.4		
% CO GAR	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02		
LOWER BURNER V					95	95	95	98	100		
TEMP COAL/AIR O TO 200C	98	98	98	90							
OIL FLOW %	3	3	3	3	3	3	3	3	3		
SEC, TERT, CORE AIR FLOW	68	68	62	62	60	60	60	60	60		
PRIMARY AIR FLOW MANO	20	20	22	22	20	20	22	22	22		
TERT WINDBOX MM WG	4	4	3	3	4	4	4	4	4	4	
LOWER BURNER POSN CORE AIR	CLOSED	CLOSED	CLOSED	CLOSED		closed	closed	closed	closed	closed	
POSN SEC AIR	75	75	65	65		60	60	60	60	60	
POSN TERT AIR	70	70	60	60		85	58	58	58	58	
POSN PRIM AIR	20	20	20	20		19	19	19	19	19	
POSN COAL FEEDER	95	95	80	70		80	80	80	80	80	
EXHAUSTER OUT PRES PA	1.4	1.4	1.45	1.5		1.3	1.3	1.3	1.35	1.3	
POSN EXHAUSTER											
POSN OIL FLOW											
SWIREL MM	125	125	125	125	125	125	125	125	125	125	
LIMESTONE FEEDER %					10	10	11	10	10	11	6	6
TIME COUNT START					10:45	11:32	12:09	13:38	14:30	15:13	15:30	16:15
LIMESTONE COUNTER START					3989	4931	5674	7471	8508	9399	9734	10222
TIME (hr)					10.75	11.53	12.15	13.63	14.50	15.22	15.50	16.25
LIMESTONE FEEDRATE KG/HR						120.3	120.5	121.1	119.7	124.3		65.1

1987

DATE BASE COAL TIME	13 MAR 87 9:30	13 MAR 87 10:00	13 MAR 87 10:30	13 MAR 87 12:00	13 MAR 87 12:30	13 MAR 87 13:00	13 MAR 87 15:00	13 MAR 87 16:00	13 MAR 87		
MW BD	17.7	17.5	17.5	17	17	17	17	17	17	17	17
WATER FLOW BD	65	65.5	63	64	64	64	64	64			
AIR FLOW BD	68	68	68	66	66	66	64	64			
GAS IN AH BD 0 TO 400C	337	340	340	335	345	346	335	340			
GAS IN AH GAR											
GAS OUT AH BD 0 TO 400C	230	230	235	230	230	234	230	235			
GAS OUT AH GAR	220	223	233	221	222	221	220	222			
AIR IN AH BD 0 TO 400C	20	20	20	20	20	20	20	20			
AIR IN AH GAR	26	26	26	26	26	26	26	26	26		
AIR OUT AH BD 0 TO 400C	195	197	200	200	201	201	200	205			
AIR IN AH GAR											
WATER IN 0 TO 200C	140	140	140	140	140	140	140	142			
WATER OUT 0 TO 200C	182	180	182	182	182	182	182	184			
AH BYPASS 0 TO 100%					CLOSED						
% OXYGEN BOARD	4	4	3.3	4.2	4.4	4	3	3.4	3.5		
% OXYGEN GAR	4.3	4.3	3.6	4.6	4.8	4.5	3.5	3.8	4		
% CO					0.02	0.02	0.02	0.02	0.02		
LOWER BURNER V											
TEMP COAL/AIR 0 TO 200C	100	101	102	102	102	102	102	102	102		
OIL FLOW %	3	3	3	3	3	3	3	3	3		
SEC, TERT, CORE AIR FLOW	67	67	67	67	62	62	62	62	62		
PRIMARY AIR FLOW MANO	26	23	23	22	22	23	23	23	23		
TERT WINDBOX MM UG	4	4	4	4	4	4	4	4	4		
LOWER BURNER POSN CORE AIR	CLOSED										
POSN SEC AIR	70	70	70	74	70	70	70	70	70		
POSN TERT AIR	65	65	65	65	65	65	65	65	65		
POSN PRIM AIR	25	21	21	20	20	20	20	20	20		
POSN COAL FEEDER	80	80	80	75	75	75	75	75	75		
EXHAUSTER OUT PRES PA	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5		
POSN EXHAUSTER											
POSN OIL FLOW											
SWIREL							125				
LIMESTONE FEEDER %				20	20	20	20	20	20	12	12
TIME COUNT START				12:02	12:34	14:11	15:02	15:41	16:26	18:12	18:20
LIMESTONE COUNTER START				11934	13274	16935	19149	20730	22469	26532	26734
TIME COUNT (hr)				12.03	12.57	14.18	15.03	15.68	16.43	18.2	18.33
LIMESTONE FEEDRATE KG/HR					251.3	226.5	260.5	243.2	231.9		151.5

1987

DATE BASE COAL	13 MAR 87	13 MAR 87	13 MAR 87	13 MAR 87	13 MAR 87	13 MAR 87	13 MAR 87	13 MAR 87	13 MAR 87
TIME UPPER BURNER	9:30	10:00	10:30	12:00	12:30	13:00	15:00	1600	
UPPER BURNER									
TEMP COAL/AIR 0 TO 200C	90	90	90	90	90	100	101	101	102
OIL FLOW %	3	3	3	3	3	3	3	3	3
SEC, TERT, CORE AIR FLOW	67	67	67	64	64	64	64	62	63
PRIMARY AIR FLOW MANO	25	25	25	25	25	25	25	23	23
TERT WINDBOX MM WG	4	4	4	4	4	4	4	4	4
POSN CORE AIR									
POSN SEC AIR	60	60	60	55	55	55	55	55	55
POSN TERT AIR	60	60	60	55	55	55	55	55	55
POSN PRIM AIR	25	25	25	25	25	25	25	24	20
POSN COAL FEEDER	80	80	80	75	76	75	75	75	75
POSN EXHAUSTER	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
POSN OIL FLOW									
SWIREL	125	125	125	125	125	125	125	125	125

Gagetown Limestone Feedrates Feb/March 1987

March 1

LIMESTONE FEEDER %	28	25	28	28	28				
TIME	13:36	14:43	14:57	16:47	17:46				
LIMESTONE COUNTER START	6996	10248	11000	16859	20118	For			
TIME COUNT (hr)	13.60	14.72	14.95	16.78	17.77	Period			
LIMESTONE FEEDRATE (KG/HR)		291.2	322.3	319.6	331.4	314.9			

March 2

LIMESTONE FEEDER %	18	18	18	18	18					
TIME COUNT START	09:57	10:35	11:09	12:58	14:19					
LIMESTONE COUNTER START	12743	26111	27270	31258	34265	For				
TIME COUNT (hr)	9.95	10.58	11.13	12.97	14.32	Period				
LIMESTONE FEEDRATE (Kg/hr)		?	210.7	217.5	222.7	218.4				

March 4

LIMESTONE FEEDER %	8	8	8	8	8		6	6	6	
LIMESTONE COUNTER START	10:20	11:00	11:43	13:18	15:00		15:45	15:55	16:04	
TIME COUNT START	35812	36495	37197	40323	41948	For	42631	42743	42839	For
TIME COUNT (hr)	10.33333	11	11.72	13.30	15.00	Period	15.75	15.92	16.07	Period
LIMESTONE FEEDRATE (Kg/hr)		97.95	97.95	197.43	95.59	130.8	91.07	67.20	64.00	65.7

March 13

LIMESTONE FEEDER %	20	20	20	20	20	20				
TIME	12:02	12:34	14:11	15:02	15:41	16:26				
LIMESTONE COUNTER START	11934	13274	16935	19149	20730	22469	For			
TIME COUNT (hr)	12.03	12.57	14.18	15.03	15.68	16.43	Period			
LIMESTONE FEEDRATE (KG/HR)		251.3	226.5	260.5	243.2	231.9	239.4			

March 12

LIMESTONE FEEDER %	10	10	11	10	10	11		6	6	
TIME COUNT START	10:45	11:32	12:09	13:38	14:30	15:13		15:30	16:15	
LIMESTONE COUNTER START	3989	4931	5674	7471	8508	9399	For	9734	10222	For
TIME COUNT (hr)	10.75	11.53	12.15	13.63	14.50	15.22	Period	15.50	16.25	Period
LIMESTONE FEEDRATE (KG/HR)		120.3	120.5	121.1	119.7	124.3	121.1	118.2	65.1	65.1

Appendix D: Limestone Feeder Calibration

Calibration of limestone feeder 27 Feb 87 by weighing can empty, filling can with limestone, weighing full and subtracting. System was run at 40% setting, ei % reading from inside back of panel was 40%. Ejector was removed, limestone was run into large barrel until flow stabilized, then can was placed under impingement plate.

time to fill can = 2 min 57 sec = 2.95 sec

wt of filled can	26.082	kilo
wt of empty can	2.3	kilo
wt of limestone	23.782	kilo

flow rate corresponding with 40%	483.6610	kilo/hr
derived flow rate at 100 %	1209.25	kilo/hr

integrator 1 kilo/count	
Integrator reading at end of test	1637
Integrator reading at beginning	1406
DIFFERENCE	231
KILOGRAMS PER COUNT 23.782/231	0.102952